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(54) **Method and apparatus for cooling multi-chip modules using integral heatpipe technology**

Verfahren und Apparat zum Kühlen von Mehrchip-Moduln durch die vollständige Wärmerohr-Technologie

Procédé et appareil pour le refroidissement de modules à plusieurs puces utilisant la technologie à caloduc intégral

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to cooling of a multi-chip module. More precisely, the present invention relates to integrating a heatpipe into the substrate of a multi-chip module to cool said module.

2. Description of the Prior Art and Related Information

An important objective of computer design is to fit the greatest number of semiconductor chips or ICs into the smallest space. Factors such as substrate design, interconnect design, cooling method, density of chip placement, etc., have great bearing on the ultimate performance of the computer. The tendency of designers to minimize the size of the computer while maximizing its computing power has led to more and more densely packed IC chips. The density of interconnects that provide the signal path between ICs must concurrently rise. Unfortunately, these densely networked interconnects have a propensity to generate heat.

By the same token, higher computing power translates to a faster rate at which instructions are executed. To execute more instructions per second, the circuits must operate at a higher frequency. Operating at a higher frequency requires higher energy input and consequently more energy is generated in the devices. A by-product of high energy input is heat.

Higher computing power also means the ability to execute larger and larger sets of instructions. As a result, the semiconductor devices used within a given area must have greater memory capacity to accommodate the increase. Thus, more energy is required to operate the increased number of memory devices. Again, more energy input results in more energy appearing as heat. It follows then that cooling of these devices should be a major concern.

In earlier days, the circuits were simply cooled by air convection circulated by a fan. But when the fan was used in conjunction with high density, multi-chip, main frame computers, the large volume of air needed for cooling necessitated powerful blowers and large ducts. Such clumsy structures in the computer occupied precious space and were noisy too.

There have been other approaches to cooling ICs. For example, U.S. Patent No. 4,748,495 to Kucharek discloses a package for cooling a high density array of IC chips and their interconnections. In this arrangement, the IC chips are mounted in a generally planar array with individual heat sinks connected to the ICs separated by flexible membrane mounts. All of the cooling structure are thus mounted on top of the ICs, separated by the membrane mounts. cooling fluid is then pumped through the cooling structures, thus carrying coolant past the areas above the ICs.

Likewise, U.S. Patent No. 4,879,629 to Tustaniwskyj et al. discloses a liquid cooled multi-chip integrated circuit module that incorporates a seamless compliant member for leakproof operation. In particular, heat sinks are disposed immediately on top of the ICs while on top of the heat sinks are disposed channels that carry liquid coolant wherein the channel is incorporated into a rigid cover. A compliant member seals off the channel area from the chip area to eliminate the possibility of leakage of liquid coolant.

Because of variations in the way ICs are mounted to the substrate, the top surface of the IC may be tilted at different angles which impairs heat conduction to the heat sink. U.S. Patent No. 5,005,638 to Goth et al. provides a unique structure to ensure solid contact between the heat sink and the IC. Goth discloses barrel shaped pistons that are spring loaded and biased toward the IC chips such that any minor tilt in the chips are compensated by the springs. Heat then rises from the IC chips up through the barrel shaped pistons and into a large body heat sink. Coolant is then pumped through the heat sink to assist in heat dissipation.

Unfortunately, with the coolant fluid disposed above the chips as in the prior art, there is always a possibility of coolant leakage. If such leakage should take place, assuming the coolant is electrically conductive, the malfunction would be catastrophic. Even if the coolant were not conductive, it would contaminate the chips leading to other reliability problems. GB-A-2 039 416 discloses an assembly of cooled semiconductor elements which are fixed in holes extending to a sealed, fluid-filled cavity in a body provided with a wick and a cooling device.

Furthermore, the structures needed for conduction of fluid and contact between the heat sink and the chips are typically very complex. These intricate structures require a great deal of attention during assembly and are usually expensive to fabricate. Accordingly, a need presently exists for a method of cooling the IC chips in a multi-chip module package.

SUMMARY OF THE INVENTION

The present invention relates to the management of latent heat energy build up within a multi-chip module package that requires exceptional cooling during operation. The present invention relies on heatpipe technology. Heatpipe technology has been used successfully for many years in moving and dispersing built-up heat in harsh environments. Indeed, this form of thermal management has been applied in the space shuttle program successfully for many years.

The present invention integrates a heatpipe directly into a multi-chip module (i.e., MCM) substrate, and is thus not simply bolted on. This is distinct from some of the prior art devices, which add discrete cooling structures to the MCM substrate. By embedding the heatpipe directly to the MCM via a thermal conduction means, it

is much simpler for product assembly and possible rework.

In a preferred embodiment, the present invention provides a heatpipe made out of copper or aluminum tubing. It can be round or flat. It can also be made from forming the metal into various other shapes. The heatpipe has a saturated wick inside that holds a working fluid, or coolant. The coolant boils and vaporizes when it comes in contact with heat energy radiating from the ICs.

The heatpipe has several functioning parts. Inside the heatpipe is the wick engulfed in coolant. The coolant moves into an evaporator region of the heatpipe, which region is disposed nearest to the ICs, and vaporizes due to the heat. The resulting vapor then travels along the heatpipe and condenses inside a condenser region, disposed away from the heat source, as it is cooled by ambient conditions. Afterward, the condensate returns to the evaporator region by capillary action through the wick.

The above-mentioned cycle is a closed loop type, never ending so long as there is heat energy being applied. In fact, the cycle is somewhat akin to a refrigeration cycle.

An MCM package cooled by the present invention is not as prone to coolant leakage because the coolant is contained within the substrate thus minimizing the possibility of contamination with the chips. Further, the simplified construction of the cooling mechanism ensures that the present invention is less expensive to build than the prior art cooling devices. Also, positive contact between the cooling mechanism of the present invention and the IC chips results in efficient heat conduction as compared to the prior art devices that required various make-shift hardware to obtain positive contact.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of a multi-chip module having a heat sink integrated into the substrate.

Figure 2 is a cross-sectional view of a preferred embodiment multi-chip module having an integrated heatpipe joined to a heat sink.

DETAILED DESCRIPTION OF THE INVENTION

The following specification describes an integral heatpipe substrate cooling apparatus. In this description, specific materials and configurations are set forth in order to provide a more complete understanding of the present invention. But it is understood by those skilled in the art that the present invention can be practiced without those specific details. In some instances, well-known elements are not described precisely so as not to obscure the invention.

The present invention relates to a multi-chip module circuit board cooled by an integrated heatpipe. Figure 1 illustrates the multi-chip module just prior to installation of the heatpipe. A packaging substrate 12 is provided to hold a plurality of semiconductor chips 10. In a preferred embodiment of the present invention, the packaging substrate 12 contains a network of cavities 34 which extend completely through the thickness of the substrate 12. Through various methods known in the art, semiconductor chips 10 are inserted into these cavities 34. Electrical interconnects (not shown) provided on the chips 10 and the packaging substrate top face 26 allow electrical communication among the chips 10 and facilitate electrical interface with external devices. For this purpose, conventional wire interconnects can be soldered to the chips 10. Or more exotic Tape Automated Bonding (TAB) techniques can be used to form the interconnects, as disclosed in co-pending application entitled "A Method and Apparatus for Interconnecting Device Using Tab In Board Technology", filed 12 August 1991, with Serial No. 742,294. After installation, the semiconductor chips 10 should preferably be recessed into the substrate 12 such that their bottom surfaces 36 are exposed. A thermal conduction means 14, embedded into the bottom face of the packaging substrate 28, is adapted to engage the bottom surfaces 36 of the chips 10. An interference fit is sufficient to mechanically hold the thermal conduction means 14 in place. Other means of attachment such as cement, mechanical fasteners, or other means known in the art are suitable to hold the conduction means 14 in position. Positive engagement is thus obtained between the bottom 36 of each chip 10 against the thermal conduction means 14. In the preferred embodiment, the thermal conduction means 14 is a copper slug. Clearly, other thermoconducting devices known in the art are acceptable in place of the copper slug.

A special bonding process may be used to insure proper heat flow from the semiconductor chip 10 to the thermal conduction means 14. More precisely, the junction between the die 10 and the thermal conduction means 14 can be formed by a process called Compliant Thermal Conduit for Printed Circuit Boards, which is disclosed in co-pending U.S. Application Serial No. 07/589,094, filed September 17, 1990, assigned to Sun Microsystems, Inc. This die attach process involves supplying a quantity of heat conductive thermoplastic material to join the die 10 to the thermal conduction means 14. At first, the thermoplastic material is fluid and flows to fill any voids in the joint. After curing, the bond stiffens insofar as no further flow occurs, but the joint remains flexible. In the preferred embodiment, the thermoplastic material should be hexagonal boron nitride. Significantly, the compliant nature of the thermoplastic material maintains a solid thermal bond even when the packaging substrate 12 undergoes flexing during assembly.

The present invention in the preferred embodiment provides a heatpipe 38 to help dissipate heat accumulating in the thermal conduction means 14. The heatpipe

38 should preferably be made from copper or aluminum. For efficient heat transfer via conduction, it is preferred that the heatpipe 38 be directly and positively attached to the thermal conduction means 14. Conventional mechanical fasteners such as clamps of screws can be used to lock the two structures together. Further, there should be no air gaps between the contacting surfaces which would impair heat conduction.

The heatpipe 38 functions similarly to a miniature refrigerator (not shown). In a typical closed circuit refrigeration cycle, the heat transfers to an evaporator which vaporizes a liquid refrigerant causing it to travel into a compressor, which in turn moves the high pressure vapor into a condenser. The condenser transfers heat out of the system and condenses the refrigerant back to liquid form. Thereafter, the condensate travels through a pressure-lowering expansion valve back into the evaporator, where the cycle repeats. The principles used here are well-known in the art and need not be explained in further detail.

Those very same principles apply in the heatpipe 38 utilized in the present invention. Inside the hollow casing 24 of the heatpipe 38 is a chamber containing refrigerant or coolant 18 and a wick 16. In the preferred embodiment, the coolant 18 is a dielectric fluorocarbon. As shown in Figure 2, one side of the heatpipe 38 is placed against the bottom surface 32 of the thermal conduction means 14 while the opposite side of the heatpipe 38 faces away. The proximal region of the heatpipe 38 closest to the thermal conduction means 14 operates as an evaporator 22, while the distal region furthest away functions as a condenser 20. Accordingly, as heat travels from the thermal conduction means 14 into the evaporator 22, the coolant 18 in that region is vaporized and moves away from the evaporator 22 to the condenser 20. In the condenser 20, the vapor cools and transitions back to its liquid form after heat is dissipated through casing 24 and out through a radiating surface 40.

After condensing to liquid form, the coolant 18 is drawn through a wick 16 back to the evaporator 22 by capillary action. As is known in the art, capillary action is due to surface tension; namely, cohesion of the liquid molecules and the adhesion of the molecules on the surface of a solid. When the adhesion is greater than the cohesion, the liquid is drawn along the wick from the wet side to the dry side. Consequently, a closed loop cycle is established in that the coolant 18 is evaporated in the evaporator 22, moves to the condenser 20 where it condenses to a liquid, and is finally drawn into the wick 16 to be carried back to the evaporator 22.

Moreover, in the preferred embodiment, the packaging substrate 12 along with the appended devices are inverted during final assembly to a motherboard (not shown). Therefore, surface 26 along with the semiconductor chips 10 all face downward toward the motherboard. As a result, the heatpipe 38 is positioned at the highest point on the substrate package 12. The condenser 20 of the heatpipe 38 is thus ideally located at a point higher in elevation than the evaporator 22. This particular orientation is conducive to optimal heat transfer and radiation away from the heat generating dice 10 since heat travels upward; and as the light-weight evaporated coolant 18 rises from the evaporator 22, the denser and heavier condensed liquid form of the coolant 18 is drawn back to the evaporator 22 by gravity, as well as through operation of the wick 16. The foregoing is only one preferred arrangement for mounting the heatpipe 38 to the thermal conduction means 14.

In an alternate embodiment (not shown), the heatpipe can extend to one side of the thermal conduction means. In this disposition, the entire region proximal to the thermal conduction means functions as a evaporator while the distal portion away from the thermal conduction means and not in engagement therewith functions as a condenser.

Heatpipes of other configurations known in the art are suitable and, depending upon space constraints or particular heat transfer application, their mounting orientation relative to the thermal conduction means can be easily varied according to the present invention. Indeed, many variations thereon are possible so the actual scope of the disclosure should be determined by reference to the appended claims.

Claims

1. A multi-chip module package having an integrated heat pipe comprising:

   a packaging substrate (12) having a top face (26) and a bottom face (28) wherein a plurality of cavities (34) are disposed into the top face of the substrate;

   a thermal conduction means (14) for conducting heat away from the substrate, embedded into the bottom face of the substrate, having a top surface (30) and a bottom surface (32) such that the top surface of the thermal conduction means is in communication with the cavities;

   a plurality of semiconductor chips (10) each having top and bottom surfaces (36) and being disposed in said cavities such that the top surface of the thermal conduction means engages the bottom surfaces of the chips;

   a network of electrical interconnects disposed on the top face of the substrate and connected to the chips; and

   a hollow casing (24) forming the heat pipe (38) for absorbing heat from the thermal conduction means, engaging the bottom face (32) of the thermal conduction means, having coolant (18), an evaporator portion (22), a condenser portion (20), and a wick (16), wherein the evaporator portion defines a proximal region of the

casing substantially adjacent to the bottom surface of the thermal conduction means, the condenser portion defines a distal region of the casing away from the evaporator portion, the wick extends a length inside the casing from the evaporator portion to the condenser portion, and wherein heat evaporates the coolant at the evaporator portion and causes the coolant to flow to the condenser portion where the coolant condenses and is drawn back to the evaporator portion through the wick by capillary action.

2. The multi-chip module package of claim 1, wherein the thermal conduction means is a first heat sink.

3. The multi-chip module package of claim 2, wherein a second heat sink is attached to the condenser portion of the hollow casing.

4. The multi-chip module package of claim 3, wherein the casing is bonded to the first heat sink by a compliant, heat-conducting thermoplastic material.

5. The multi-chip module package of claim 4, wherein the compliant, heat-conducting thermoplastic material is used to bond the chips to the heat sink.

6. The multi-chip module package of claim 5, wherein the compliant, heat-conducting thermoplastic material is hexagonal boron nitride.

7. The multi-chip module package of claim 6, wherein the hollow casing is formed from copper tubing having opposed openings that are sealed closed.

8. The multi-chip module package of claim 6, wherein the hollow casing is formed from aluminum tubing having opposed openings that are sealed closed.

9. The multi-chip module package of claim 7, wherein the second heat sink has fins to dissipate heat.

10. The multi-chip module package of claim 9, wherein the wick is in the form of a closed loop.

11. The multi-chip module package of claim 10, wherein the multi-chip module is inverted and the electrical interconnects are attached to a motherboard.

12. The multi-chip module package of claim 11, wherein the coolant is a dielectric fluorocarbon.

13. The multi-chip module package of claim 12, wherein the first heat sink is a copper slug.

14. The multi-chip module package of claim 13, wherein the copper slug is further adapted to mount to a third heat sink.

15. A process for using an integrated heat pipe to cool a multi-chip module that emits heat, the steps comprising of:

providing a packaging substrate (12) having a plurality of cavities (34) disposed in a top face (26);
incorporating a thermal conduction means (14) into a bottom face (28) of the packaging substrate such that the cavities are in communication with the thermal conduction means;
embedding semiconductor chips (10) into the cavities such that the thermal conducting means is in contact with the chips;
attaching a hollow casing (24), which casing forms the heat pipe (38), to the thermal conduction means, wherein the hollow casing includes an evaporator portion (22) disposed adjacent the thermal conduction means, a condenser portion (20) disposed at a distal region of the casing, and a wick (16) enclosed therein extending from the evaporator portion to the condenser portion and impregnated with a coolant (18) that partially fills the hollow casing;
evaporating the coolant in the evaporating portion into a vapor by absorbing the heat transferred into the hollow casing from the thermal conduction means, wherein the vapor moves to the condenser portion;
condensing the coolant into a liquid in the condenser portion by dissipating the heat from the vapor inside the condensing means; and
drawing the liquid coolant by capillary action through the wick to the evaporator portion.

16. The process according to claim 16, wherein the step of drawing the liquid coolant by capillary action is performed by a wick.

17. The process according to claim 17, wherein the thermal conduction means is a heat sink.

18. The process according to claim 18, wherein the coolant is a dielectric fluorocarbon.

19. The process according to claim 19, wherein a compliant, heat-conducting thermoplastic material is applied between the chips and the heat sink, and allowed to cure.

Patentansprüche

1. Mehrchip-Modulanordnung, die ein integriertes Wärmerohr hat, umfassend:

ein Einkapselungssubstrat (12) mit einer Deckseite (26) und einer Bodenseite (28), wobei mehrere Vertiefungen (34) in die Deckseite des Substrats eingebracht sind;
ein zum Ableiten der Wärme vom Substrat in die Bodenseite des Substrats eingebettetes Wärmeleitmittel (14), das eine Deckseite (30) und eine Bodenseite (32) dergestalt hat, daß die Deckseite des Wärmeleitmittels in Verbindung ist mit den Vertiefungen;
eine Mehrzahl von Halbleiterchips (10), die jeweils eine Deck- und eine Bodenseite (36) haben und so in den genannten Vertiefungen angeordnet sind, daß die Deckseite des Wärmeleitmittels sich an die Bodenseite der Chips anschmiegt;
ein an der Deckseite des Substrats angeordnetes und mit den Chips verbundenes Netzwerk von elektrischen Verbindungen; und
ein hohles Gehäuse (24), das das Wärmerohr (38) zum Absorbieren von Wärme von dem Wärmeleitmittel bildet, und das sich an die Bodenseite (32) des Wärmeleitmittels anschmiegt, enthaltend ein Kühlmittel (18), einen Verdampfungsteil (22), einen Kondensationsteil (20) und einen Docht (16), wobei der Verdampfungsteil einen im wesentlichen zur Bodenseite des Wärmeleitmittels benachbarten Bereich des Gehäuses definiert, der Kondensationsteil einen von dem Verdampfungsteil entfernten Bereich des Gehäuses definiert, der Docht sich innerhalb des Gehäuses vom Verdampfungsteil zum Kondensationsteil erstreckt, und wobei Hitze das Kühlmittel am Verdampfungsteil verdampft und bewirkt, daß das Kühlmittel zum Kondensationsteil fließt, wo das Kühlmittel kondensiert und durch die Kapillarwirkung im Docht zum Verdampfungsteil zurückgezogen wird.

2. Die Mehrchip-Modulanordnung nach Anspruch 1, wobei das Wärmeleitmittel ein erster Kühlkörper ist.

3. Die Mehrchip-Modulanordnung nach Anspruch 2, wobei ein zweiter Kühlkörper an den Kondensationsteil des hohlen Gehäuses angeschlossen ist.

4. Die Mehrchip-Modulanordnung nach Anspruch 3, wobei das Gehäuse mit dem ersten Kühlkörper mittels eines elastischen, wärmeleitenden, thermoplastischen Materials verbunden ist.

5. Die Mehrchip-Modulanordnung nach Anspruch 4, wobei das elastische, wärmeleitende, thermoplastische Material die Chips mit dem Kühlkörper verbindet.

6. Die Mehrchip-Modulanordnung nach Anspruch 5, wobei das elastische, wärmeleitende, thermoplastische Material hexagonales Bornitrid ist.

7. Die Mehrchip-Modulanordnung nach Anspruch 6, wobei das hohle Gehäuse gebildet ist aus Kupferrohren, die gegenüberliegende versiegelte Öffnungen haben.

8. Die Mehrchip-Modulanordnung nach Anspruch 6, wobei das hohle Gehäuse gebildet ist aus Aluminiumrohren, die gegenüberliegende versiegelte Öffnungen haben.

9. Die Mehrchip-Modulanordnung nach Anspruch 7, wobei der zweite Kühlkörper Rippen hat, um die Hitze zu verteilen.

10. Die Mehrchip-Modulanordnung nach Anspruch 9, wobei der Docht in der Form einer geschlossenen Schleife ausgebildet ist.

11. Die Mehrchip-Modulanordnung nach Anspruch 10, wobei das Mehrchip-Modul auf dem Kopf stehend angeordnet ist, und die elektrischen Verbindungen an der Mutterplatine befestigt sind.

12. Die Mehrchip-Modulanordnung nach Anspruch 11, wobei das Kühlmittel ein nichtleitender Fluorkohlenstoff ist.

13. Die Mehrchip-Modulanordnung nach Anspruch 12, wobei der erste Kühlkörper ein Kupferanpaßkörper ist.

14. Die Mehrchip-Modulanordnung nach Anspruch 13, wobei auf dem Kupferanpaßkörper ein dritter Kühlkörper befestigt werden kann.

15. Verfahren zur Nutzung eines integrierten Wärmerohres zum Kühlen eines Wärme abgebenden Mehrchip-Moduls, die Schritte enthaltend:

Zur-Verfügung-Stellen eines Einkapselungssubstrats (12), das mehrere Vertiefungen (34) hat, die in der Deckseite (26) angeordnet sind;
Einbringen eines Wärmeleitmittels (14) in die Bodenseite (18) des Einkapselungssubstrats derart, daß die Vertiefungen in Kontakt stehen mit dem Wärmeleitmittel;
Einbetten von Halbleiterchips (10) in die Vertiefungen derart, daß das Wärmeleitmittel in Kontakt ist mit den Chips;
Befestigen eines ein Wärmerohr (38) bildenden hohlen Gehäuses (24) an das Wärmeleitmittel, wobei das hohle Gehäuse einen Verdampfungsteil (22), der zum Wärmeleitmittel benachbart angeordnet ist, einen Kondensationsteil (20), der im entfernten Bereich des

Gehäuses angeordnet ist, und einen Docht (16) enthält, der im hohlen Gehäuse eingeschlossen ist, sich vom Verdampfungsteil zum Kondensationsteil erstreckt und von einem Kühlmittel (18) benetzt ist, das das hohle Gehäuse teilweise füllt;
Verdampfen des Kühlmittels im Verdampfungsteil durch Absorption der Wärme, die in das hohle Gehäuse vom Wärmeleitmittel transferiert wurde, wobei der Dampf sich zu dem Kondensationsteil bewegt;
Kondensieren des Kühlmittels im Kondensationsteil durch Abführen der Wärme aus dem im Kondensationsmittel befindlichen Dampf; und
Ziehen des flüssigen Kühlmittels durch Kapillarwirkung durch den Docht zum Verdampfungsteil.

16. Verfahren nach Anspruch 15, wobei der Schritt des Ziehens des flüssigen Kühlmittels durch Kapillarwirkung mittels eines Dochtes ausgeführt wird.

17. Verfahren nach Anspruch 16, wobei das thermische Leitungsmittel ein Kühlkörper ist.

18. Verfahren nach Anspruch 17, wobei das Kühlmittel ein nichtleitender Fluorkohlenwasserstoff ist.

19. Verfahren nach Anspruch 18, wobei ein flexibles, wärmeleitendes, thermoplastisches Material zwischen den Chips und dem Kühlkörper aufgebracht wird und trocknen gelassen wird.

Revendications

1. Boîtier de module à plusieurs puces comportant un caloduc intégré comprenant :

un substrat de boîtier (12) ayant une face supérieure (26) et une face inférieure (28), dans lequel plusieurs cavités (34) sont disposées dans la face supérieure du substrat;

un moyen de conduction thermique (14) pour conduire la chaleur hors du substrat, incorporé dans la face inférieure du substrat, ayant une face supérieure (30) et une face inférieure (32), tel que la surface supérieure du moyen de conduction thermique est en communication avec les cavités ;

plusieurs puces à semi-conducteur (10) ayant chacune des surfaces supérieures et inférieures (36), et disposées dans lesdites cavités de façon que la surface supérieure du moyen de conduction thermique contacte les surfaces inférieures des puces ;

un réseau d'interconnexions électriques disposées sur la face supérieure du substrat, et connectées aux puces ; et

une enveloppe creuse (24) constituant le caloduc (38), pour absorber la chaleur provenant du moyen de conduction thermique, en contact avec la face inférieure (32) du moyen de conduction thermique, comportant un agent de refroidissement (18), une partie formant évaporateur (22), une partie formant condenseur (20) et une mèche (16), dans lequel la partie formant évaporateur définit une zone proche de l'enveloppe, sensiblement adjacente à la surface inférieure du moyen de conduction thermique, la partie formant condenseur définit une zone distale de l'enveloppe, éloignée de la partie formant évaporateur, la mèche s'étend d'une certaine longueur à l'intérieur de l'enveloppe depuis la partie formant évaporateur vers la partie formant condenseur, et dans lequel la chaleur fait évaporer l'agent de refroidissement dans la partie formant évaporateur, et provoque l'écoulement de l'agent de refroidissement vers la partie formant condenseur, où l'agent de refroidissement se condense et est attiré en retour vers la partie formant évaporateur à travers la mèche, par action capillaire.

2. Boîtier de module à plusieurs puces selon la revendication 1, dans lequel le moyen de conduction thermique est un premier dissipateur de chaleur.

3. Boîtier de module à plusieurs puces selon la revendication 2, dans lequel un second dissipateur de chaleur est fixé à la partie formant condenseur de l'enveloppe creuse.

4. Boîtier de module à plusieurs puces selon la revendication 3, dans lequel l'enveloppe est reliée au premier dissipateur de chaleur par un matériau thermoplastique souple, conducteur de la chaleur.

5. Boîtier de module à plusieurs puces selon la revendication 4, dans lequel le matériau thermoplastique souple, conducteur de la chaleur est utilisé pour relier les puces au dissipateur de chaleur.

6. Boîtier de module à plusieurs puces selon la revendication 5, dans lequel le matériau thermoplastique souple, conducteur de la chaleur est du nitrure de bore hexagonal.

7. Boîtier de module à plusieurs puces selon la revendication 6, dans lequel l'enveloppe creuse est formée d'un tube de cuivre ayant des ouvertures opposées qui sont fermées hermétiquement.

8. Boîtier de module à plusieurs puces selon la revendication 6, dans lequel l'enveloppe creuse est formée d'un tube d'aluminium ayant des ouvertures opposées qui sont fermées hermétiquement.

9. Boîtier de module à plusieurs puces selon la revendication 7, dans lequel le second dissipateur de chaleur comporte des ailettes pour dissiper la chaleur.

10. Boîtier de module à plusieurs puces selon la revendication 9, dans lequel la mèche est sous la forme d'une boucle fermée.

11. Boîtier de module à plusieurs puces selon la revendication 10, dans lequel le module à plusieurs puces est inversé, et les interconnexions électriques sont fixées à une carte-mère.

12. Boîtier de module à plusieurs puces selon la revendication 11, dans lequel l'agent de refroidissement est un fluorocarbone diélectrique.

13. Boîtier de module à plusieurs puces selon la revendication 12, dans lequel le premier dissipateur de chaleur est une pièce de cuivre.

14. Boîtier de module à plusieurs puces selon la revendication 13, dans lequel la pièce de cuivre est en outre susceptible d'être monté, sur un troisième dissipateur de chaleur.

15. Procédé pour utiliser un caloduc intégré pour refroidir un module à plusieurs puces qui émet de la chaleur, les étapes consistant à :

prévoir un substrat de boîtier (12) ayant plusieurs cavités (34) disposées dans une face supérieure (26) ;

incorporer un moyen de conduction thermique (14) dans une face inférieure (28) du substrat de boîtier, de façon que les cavités soient en communication avec le moyen de conduction thermique ;

encastrer des puces à semi-conducteur (10) dans les cavités, de façon que le moyen de conduction thermique soit en contact avec les puces ;

relier une enveloppe creuse (24), laquelle enveloppe constitue le caloduc (38), au moyen de conduction thermique, l'enveloppe creuse comportant une partie formant évaporateur (22), disposée de façon adjacente au moyen de conduction thermique, une partie formant condenseur (20) située en une zone distale de l'enveloppe, et une mèche (16) qui y est enfermée, s'étendant depuis la partie formant évaporateur vers la partie formant condenseur, et imprégnée d'un agent de refroidissement (18) qui remplit partiellement l'enveloppe creuse ;

évaporer en vapeur l'agent de refroidissement dans la partie d'évaporation, en absorbant la chaleur transférée vers l'enveloppe creuse en provenance du moyen de conduction thermique, la vapeur se déplaçant vers la partie formant condenseur ;

condenser l'agent de refroidissement en liquide dans la partie formant condenseur, en dissipant la chaleur provenant de la vapeur à l'intérieur du moyen de condensation; et

attirer l'agent de refroidissement liquide par action capillaire à travers la mèche vers la partie formant évaporateur.

16. Procédé selon la revendication 16, dans lequel l'étape d'extraction de l'agent de refroidissement liquide par action capillaire est effectuée par une mèche.

17. Procédé selon la revendication 17, dans lequel le moyen de conduction thermique est un dissipateur de chaleur.

18. Procédé selon la revendication 18, dans lequel l'agent de refroidissement est un fluorocarbone diélectrique.

19. Procédé selon la revendication 19, dans lequel un matériau thermoplastique souple, conducteur de la chaleur est appliqué entre les puces et le dissipateur de chaleur, et durci.

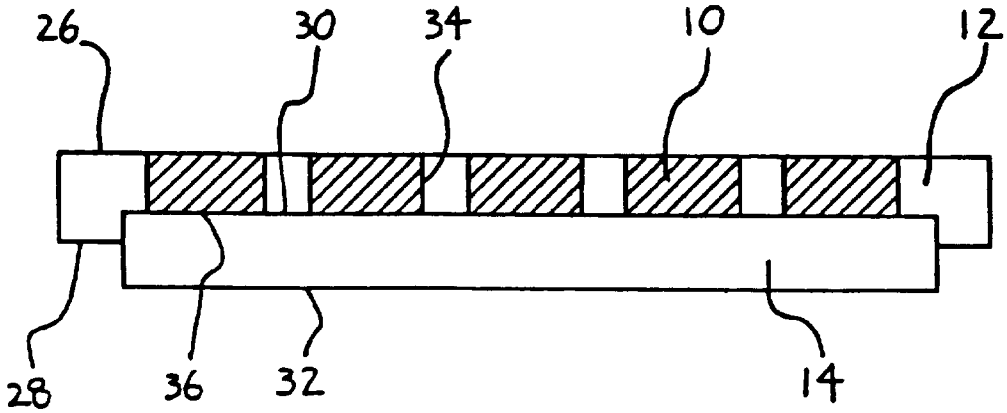

FIG. 1

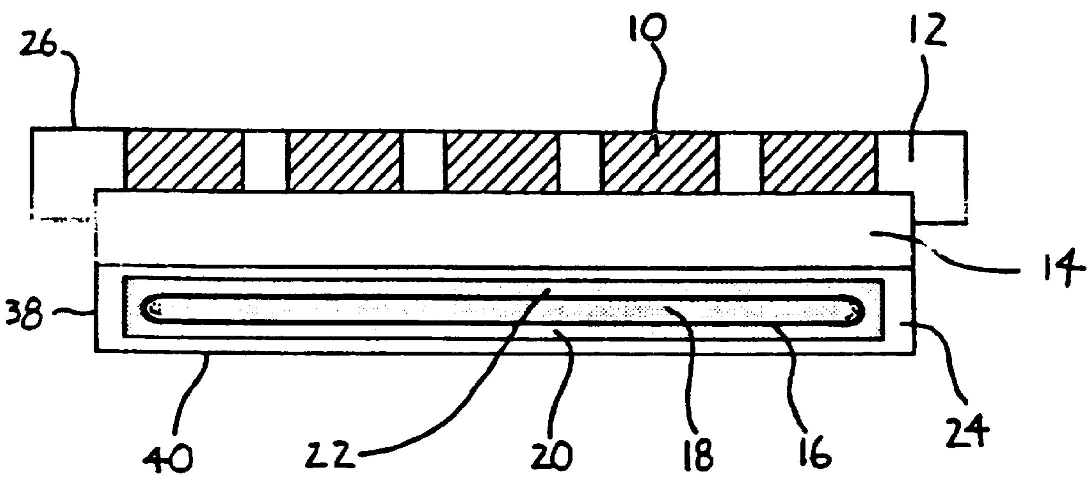

FIG. 2